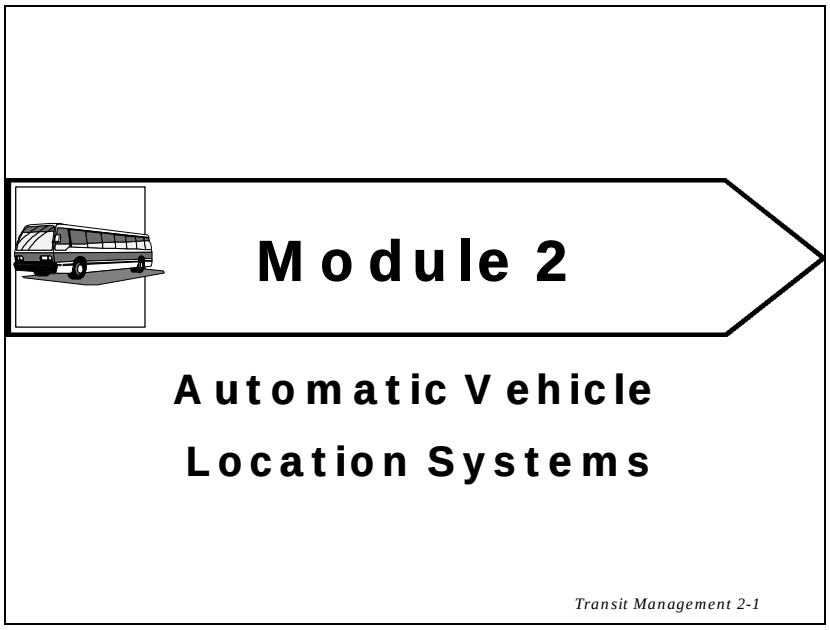
Module 2: Automatic Vehicle Location Systems



TRANSIT MANAGEMENT TRAINING ROADMAP	
	Module 1: Introduction to ITS and APTS
	Module 2: Automatic Vehicle Location Systems
	Module 3: Automated Transit Information
	Module 4: Transit Telecommunications
	Module 5: Transit Operations Software
	Module 6: Paratransit Computer-Aided Dispatch
	Module 7: Electronic Fare Payment
	Module 8: Technologies for Small Urban and Rural Transit Systems
	Module 9: Stages of ITS Project Deployment
	Module 10: What Can ITS Do for Me?

State-of-the-art Location Technologies:
- GPS
- Differential GPS
- other
- combination systems

Data Transmission to dispatch:
- polling
- exception reporting

Module 2: Automatic Vehicle Location Systems
1.5 Hours

Introduction

Schedule The following table shows the times and activities for this module.

Time	Activity/Topic
3 min.	*Lecture/Discussion:* Introduction
12 min.	*Lecture/Discussion:* What is AVL?
20 min.	*Lecture/Discussion:* Location Technologies
15 min.	*Lecture/Discussion:* Data Transmission to Dispatch
10 min.	*Lecture/Discussion:* Examples
30 min.	Exercise 2-1: Custom Course Notes
90 min.	Total Time

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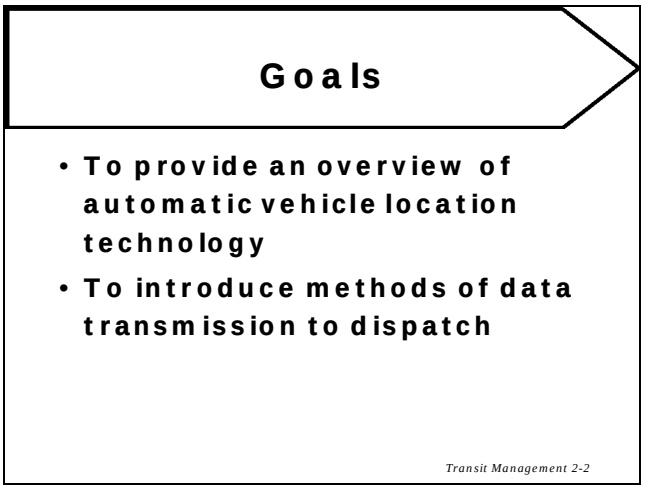
Introduction, Continued

Slide: Goals



Goals

Say: The goals of this module are to introduce the two essential parts of an automatic vehicle location (AVL) system. They are:

- location technology
- methods of data transmission to dispatch

Location technology will include:

- the state-of-the-art automatic vehicle location technology:
  - ◊ Global Positioning System (GPS)
- other types of automatic vehicle location technology:
  - ◊ signpost and odometer
  - ◊ radionavigation/location
  - ◊ dead reckoning
- combination systems

- The module will also introduce the two most common methods of data transmission from the vehicle to dispatch:
  - ◊ polling
  - ◊ exception reporting

Continued on next page

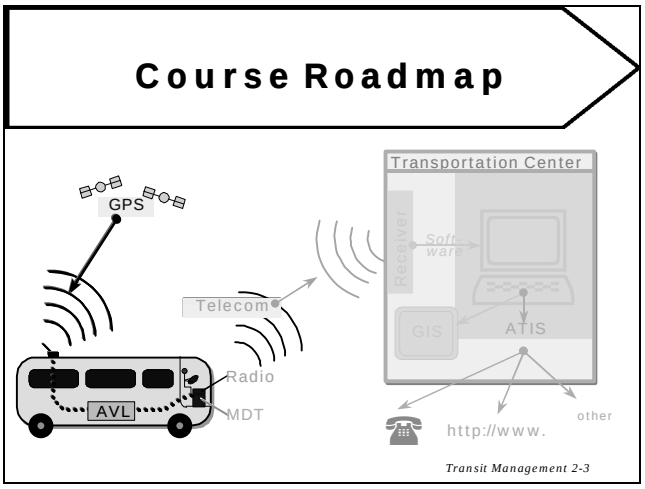
Introduction, Continued

Objectives

Read the module objectives:

- Given a set of student materials, students will identify the most appropriate AVL system for their agency.
- Given an APTS Technology Reference table, students will list three benefits of using an AVL system in their agency.

Slide: Course Roadmap



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Introduction, Continued

Orient with the roadmap

Show slide.

Show the class where they are with the roadmap on page 1 of their SG.

Explain that we've seen one of the three parts of the ITS Infrastructure (traveler information) that we discussed in Module 1.

AVL begins the discussion of the second, **transit fleet management**, which incorporates many of the vehicle-based APTS technologies and innovations for more effective vehicle and fleet planning, scheduling, and operations.

- Fleet management focuses on the vehicle, improving the efficiency and effectiveness of the service provided (the "supply side"), and on passenger safety.
- By making transit more efficient and reliable, it should be more attractive to prospective riders and less costly to the municipalities they serve.

The technologies we will discuss in this module are:

- communications systems
- geographic information systems (GIS)
- automatic vehicle location (AVL)
- automatic passenger counters (APC)
- transit operations software

Source: APTS State of the Art Update '98, p. 2-1

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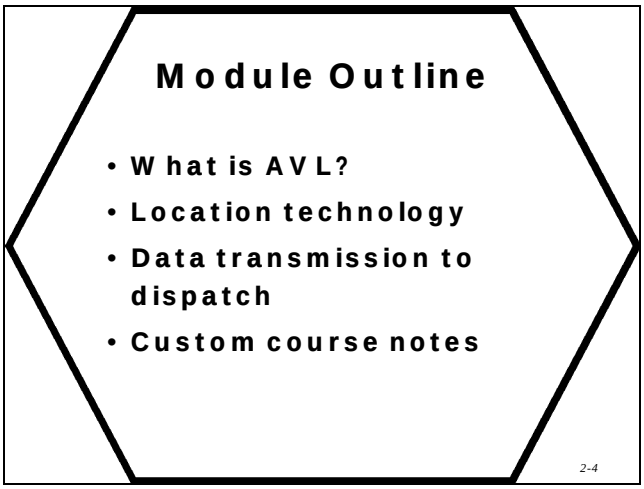
Introduction, Continued

Slide: Module Outline



Module outline

Explain the module outline.

AVL has two parts

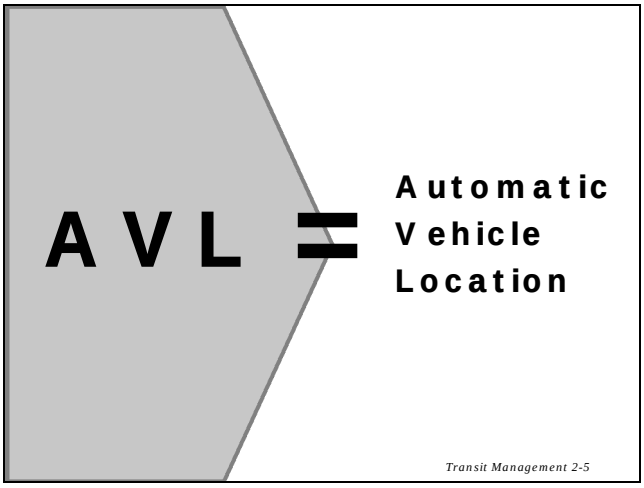
Explain that an Automatic Vehicle Location (AVL) system is technology that allows an agency to improve its fleet management.

These systems are usually composed of two specific parts:
- locating the vehicle
- communicating the location to a central dispatch

What Is AVL?

Length 12 minutes

Slide: Automatic Vehicle Location



AVL

Explain that the common acronym for automatic vehicle location is AVL.

Say: Let's look at some basic features of automatic vehicle location.

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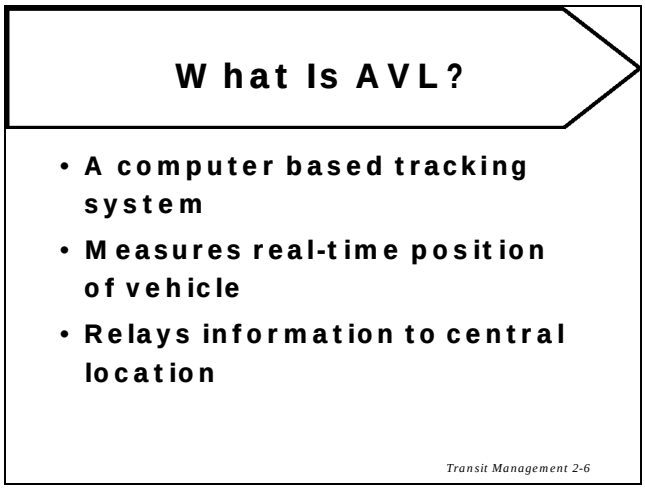
What Is AVL?, Continued

Slide: What Is AVL?



What is AVL?

AVL systems:

- are computer-based vehicle tracking systems
- use a positioning system
  - ◊ usually GPS
  - ◊ but also could use sign post and odometer, or dead reckoning
- transmit vehicle location to the transit dispatch center as required
- can also minimize voice transmissions by providing location data messages

AVL vs. AVM

Say: When talking about Automatic Vehicle Location (AVL), you may also hear the acronym AVM (Automatic Vehicle Monitoring). AVL and AVM are sometimes used interchangeably, but in general:

- AVL includes vehicle location and tracking systems.
- AVM couples AVL location data with data on vehicle status and operating conditions, such as oil pressure, engine temperature, etc.

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What Is AVL?, Continued

Real-time tracking

Explain that the two keys to an Automatic Vehicle Location system—locating the vehicle and communicating that information back to a central dispatch—work together to form a real-time computer based tracking system.

AVL systems generally use technology on the vehicle and at the central dispatch to:

- calculate the vehicle location on board
- store the position information on board for a short time
  - ◊ from a few seconds to several minutes or can depend on an outside trigger
- inform the dispatch of the vehicle position
  - ◊ sometimes at set time intervals or locations
  - ◊ sometimes the position information is sent to the dispatch only when dispatch needs the information

AVL uses

AVL systems are designed to help agencies:

- dispatch
- track
- communicate
- manage mobile assets (e.g., transit vehicles, equipment inventory, equipment repair, and human resources)
- have records of where vehicles were at a given time and date

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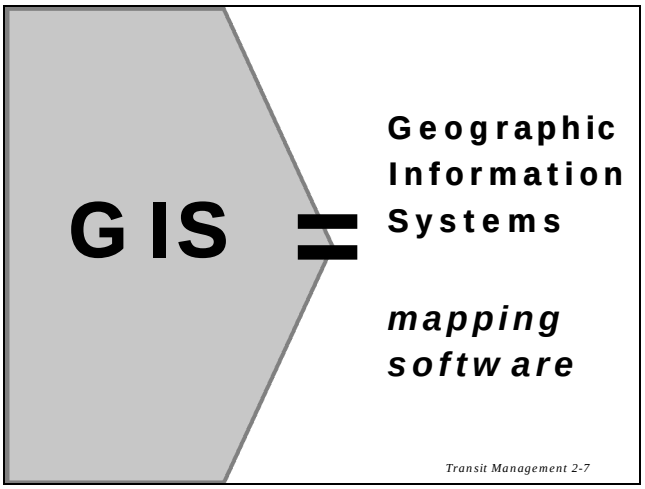
What Is AVL?, Continued

Slide: GIS



GIS

Explain how geographic information system (GIS) enables the effective working of an AVL system:

A GIS is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates.

- This relationship allows users to make queries and selections of database records based on both geographic proximity and attribute values.

In the past few years, the use of GIS by public transportation systems has increased significantly. The most frequent uses include:

- the application of urban bus service route
- schedule information maintenance
- presentation of this information to customers

Note to instructor: The appendix in Module 9 of this course contains more information about National GIS.
Source: APTS State of the Art Update '98, p. xii

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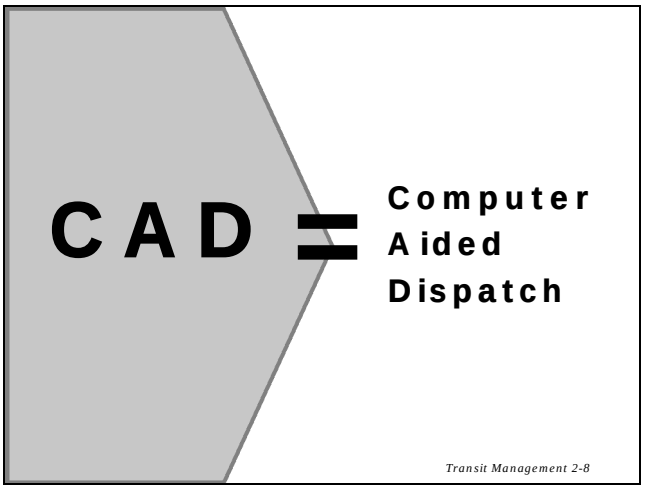
What Is AVL?, Continued

Slide: CAD



CAD

Explain how CAD relates to AVL:

Computer-aided dispatch (CAD) is a type of transit operations software that can combine with AVL to facilitate tracking the on-time status of each vehicle in a fleet.

- Not only do operators and dispatchers benefit from regular updating of on-time status, but customers benefit as well through the information systems.

Source: APTS State of the Art Update '98, p. xv

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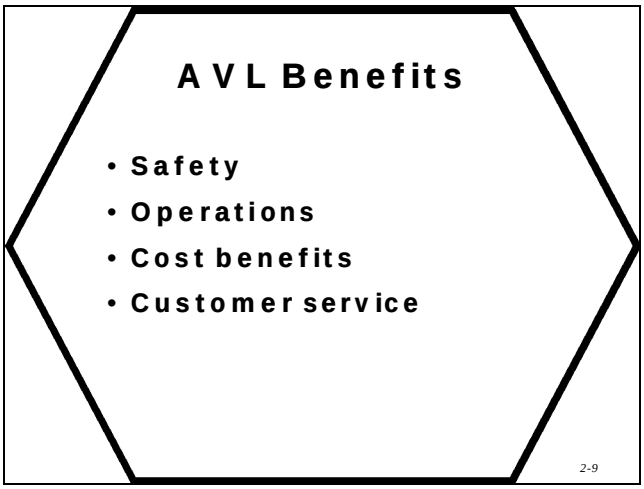
What Is AVL?, Continued

Slide: AVL Benefits



AVL benefits

Explain benefits overview slide.

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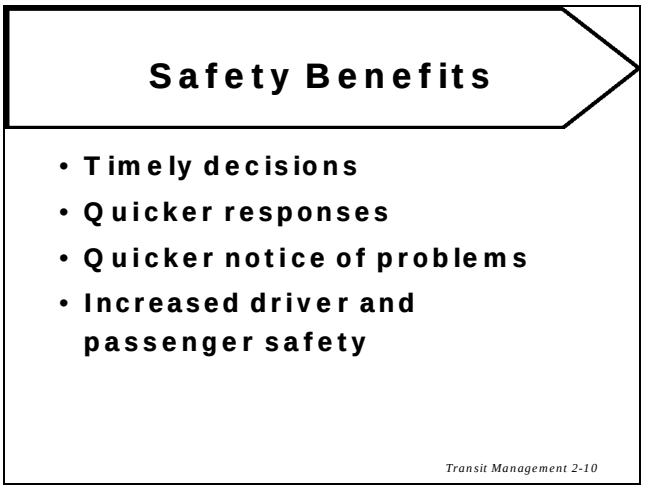
What Is AVL?, Continued

Slide: Safety Benefits



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What Is AVL?, Continued

Increased safety

Say: AVL increases safety by providing:

- timely decisions and response in an emergency
  - ◊ e.g., if a passenger has a medical emergency, AVL can show dispatch exactly where the vehicle is and pass that information to an emergency vehicle more quickly.

- quicker responses to disruptions in schedule
  - ◊ e.g., traffic congestion, bus running late, etc.
  - ◊ e.g., AVL information passed on to the passenger, such as a sudden snowstorm causing a particular trolley to be 20 minutes late, can help prevent that passenger from waiting on a platform late at night.

- quicker notice of mechanical problems with vehicles
  - ◊ e.g., dispatch knows when and where to send a replacement bus for a bus with a flat tire.
  - ◊ e.g., when combined with in-vehicle diagnostics, dispatch knows when to send a replacement bus before it has the flat tire.

- increased driver and passenger safety and security
  - ◊ e.g., a silent alarm (which we'll talk about in a few minutes) can be sent to dispatch if a dangerous passenger is threatening other passengers, and dispatch can contact the appropriate authorities.

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What Is AVL?, Continued

APTS reports

Say: Safety benefits reported about APTS in the benefits document on the U.S. DOT APTS web site include:

- Several instances in cities with AVL equipped buses where bus operators have observed accidents, crimes, or other situations outside the bus, which warrant quick response by emergency personnel. The AVL system's communication and location capability has allowed the emergency personnel to be quickly notified and directed to the exact location of the trouble.

- Kansas City Area Transit Authority (KCATA) dispatchers estimate that response times to bus operator calls for assistance have been reduced from 7-15 minutes to 3-4 minutes.

- Public safety alerts can be forwarded to buses to avoid a high-risk area.
  - ◊ e.g., buses can be rerouted if a fire might endanger a route

- The location of a bus can be forwarded to public safety agencies if an operator detects and signals a problem.

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What Is AVL?, Continued

Increased safety example

Say: Denver Regional Transportation District (RTD) installed an AVL computer aided dispatch system, and reported the following:

- In Denver, a man who had just robbed a convenience store was observed to have boarded an RTD bus. The police informed the dispatcher, who used the Computer-Aided-Dispatch AVL system to identify which bus the suspect would likely have boarded. The transit control head's message capability was used to confirm the suspect's presence on the bus. The police were then directed to a point where the bus could be intercepted. The suspect was apprehended.

- In Denver, a man brandishing a knife was thought to have boarded an RTD bus. The driver signaled to dispatch by using the silent alarm. Through the CAD AVL system, the correct bus was identified, the police notified, and the man arrested.

- Also in Denver, a bus passenger had a seizure. RTD was able to notify emergency response personnel of the incident and its location, and an ambulance was at the scene within eight minutes.

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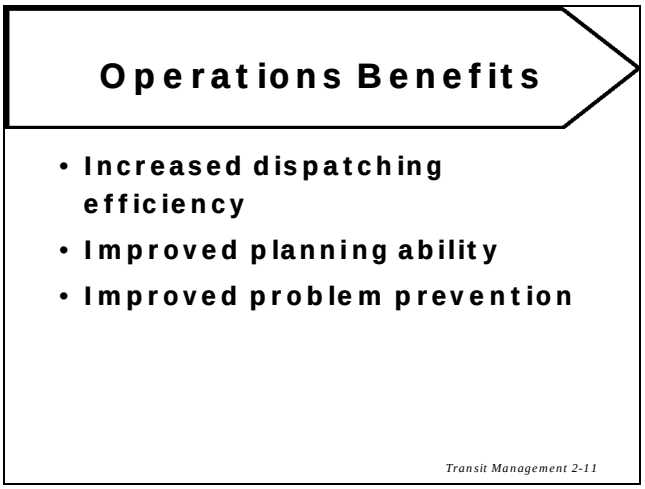
What Is AVL?, Continued

Slide: Operations Benefits



Operations benefits

Explain slide.

- Increased dispatching efficiency
  - ◊ e.g., AVL helps to keep vehicle and dispatch clocks synchronized.
- Improved planning ability
  - ◊ e.g., planners have more information available to them.
- Improved problem prevention
  - ◊ e.g., AVL coupled with vehicle monitoring helps to identify vehicle problems before they are serious.

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What Is AVL?, Continued

Improved operations example

Say: Operational benefits reported in the benefits document on the U.S. DOT APTS web site include:

- Milwaukee County Transit System claims that on-time performance has improved from 90% to 94% after implementing their AVL system, even though the system is not fully operational.
- The Mass Transit Administration of Maryland reported a 23% increase in on-time performance of buses in Baltimore in their test of AVL equipped buses on a few routes.
- Kansas City Area Transit Authority (KCATA's) on-time performance (from one minute early to three minutes late) improved from 80% to 90% after AVL installation.

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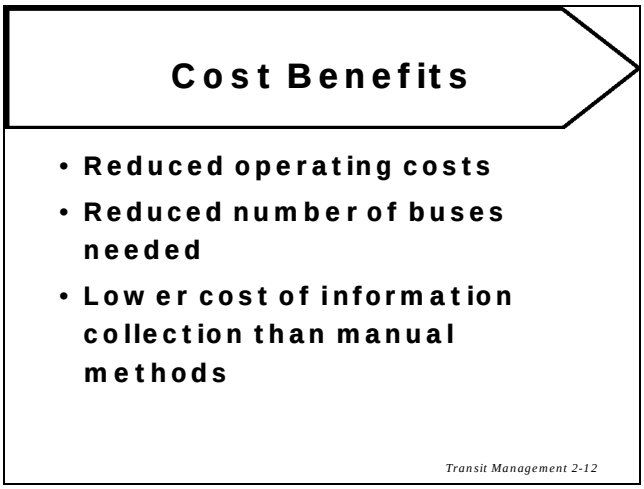
What Is AVL?, Continued

Slide: Cost Benefits



Costs

Explain overall costs before discussing cost benefits.

Say: First, a word of caution before we talk about what costs savings you might experience with AVL. According to a recent study, "an AVL system is a significant investment." Agencies requesting proposals and expecting "system costs would be on the order of a few million dollars" received proposals "three to five times the original estimates."

Source: Synthesis for Transit Practice 24: AVL Systems for Bus Transit, by Paula E. Okunieff; Transportation Research Board, 1997.

Other costs that should be considered include warranty costs, telecommunication and maintenance charges, and training charges.

Say: We will be looking at comparative costs of the choices available in AVL systems in this module.

Continued on next page

What Is AVL?, Continued

Cost benefits

Explain the slide.

Decreased costs example

Say Cost benefits reported about APTS in the benefits document on the U.S. DOT APTS web site include:

- A large transit authority has estimated that AVL generated data would allow it to reduce the number of schedule adherence checkers and save approximately $1.5 million per year.
- Although KCATA did not eliminate street supervisory personnel, it achieved some savings because with AVL, absences or temporary reassignment of supervisors was less of a problem.
- London, Ontario's AVL system will provide schedule adherence on a continuing basis, thus saving the $40,000 to $50,000 previously spent on each schedule adherence survey.
- Milwaukee County Transit System plans to re-deploy a number of street supervisors when the CAD AVL system is fully operational.

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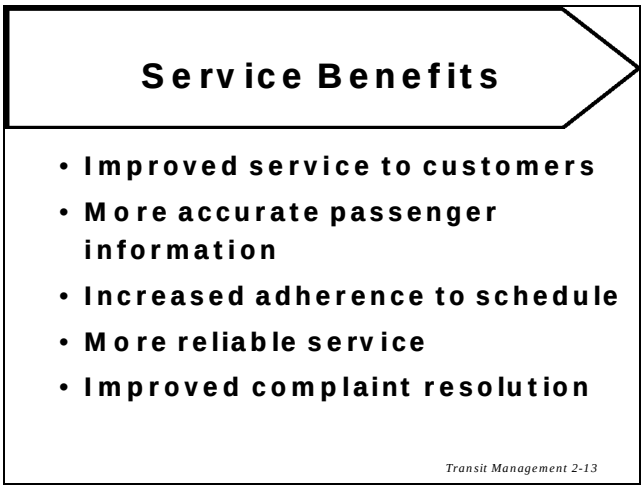
What Is AVL?, Continued

Slide: Service Benefits



Schedule adherence

Say: A number of transit operators have claimed improved schedule adherence after AVL implementation, including:

- County of Lackawanna Transit System (Scranton, PA)
- Broward County Division of Mass Transit (FL)
- Beaver County Transit Authority (Rochester, PA)

Complaint resolution

Say: Also reported in the benefits document on the U.S. DOT APTS web site :

- In Denver, a bus operator initially was not paid for a day that she worked. The CAD AVL log-in requirement proved that she did work on that day.

- In Milwaukee, a passenger complained that a bus had left a stop too early, a fact that the bus operator disputed. The playback capability of the CAD AVL system corroborated the operator's claim.

Say: In a related issue, AVL can help resolve disputes about "no-shows" for paratransit, which is a big issue.

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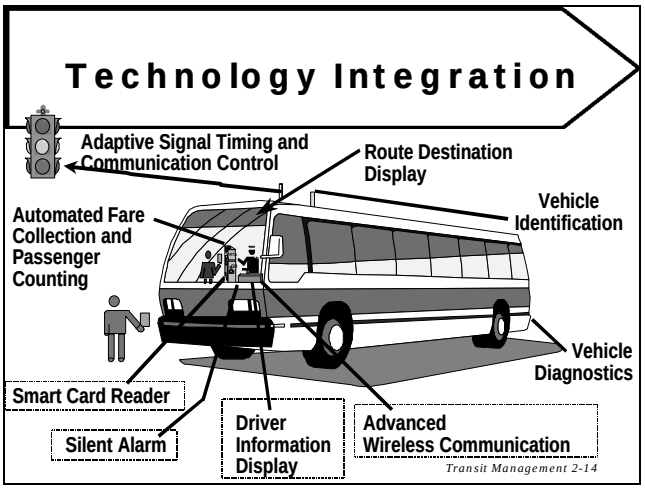
What Is AVL?, Continued

Slide: Technology Integration



Technology integration

Explain that Automatic Vehicle Location systems are currently among the most popular of the APTS technology applications because the information they provide can be linked to or drive other applications.

For instance, almost all AVL systems being installed now can be linked to some kind of advanced traveler information system because the information from the AVL system can feed the advanced traveler information system.

The integration of transit and highway traveler information systems is an important element of a metropolitan ITS system.

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What Is AVL?, Continued

Considerations

Say If you are considering an AVL system, you will want also to consider some of the technologies and applications that can be integrated with it, including:

- traveler information systems (which we talked about in Module 2)
- schedule adherence monitoring
- schedule planning
- silent alarm (we'll talk more about this in a minute)
- vehicle component monitoring systems
  - ◊ e.g., engine conditions
- automatic passenger counters
- computer aided dispatch (we'll talk about this in more detail in Module 6)
- traffic signal preferential treatment
- electronic fare payment systems (we'll talk about this in Module 7)
- geographic information systems (GIS) for mapping (we'll talk about this more in Module 5)

Most of these technologies cannot stand alone. They rely on telecommunications to convey the information from where it is created to where it is needed or used. Telecommunications, then, is the glue that binds all of this technology together. We'll be discussing transit telecommunications in Module 4 later.

Most agencies cannot install everything at once, since the scale of such a project would be too large, but you should plan how future systems might be integrated.

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What Is AVL?, Continued

Silent alarm

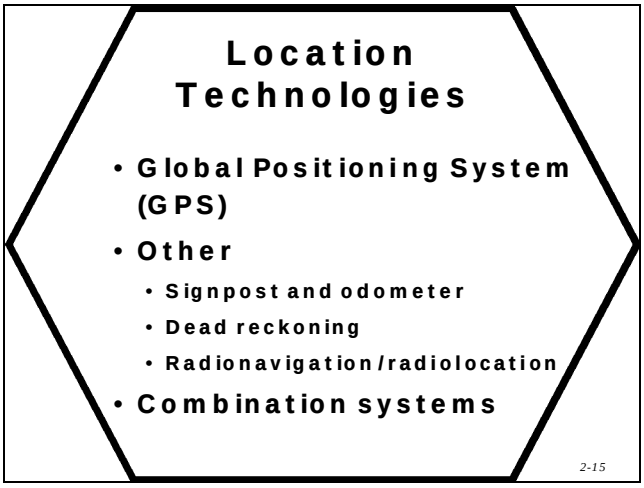
Explain that most AVL systems include a silent alarm, i.e., a silent way for the operator to signal dispatch in the case of an emergency. Silent alarms are relatively inexpensive when coupled with an AVL system.

Bus operators in transit systems with AVL report a greatly increased feeling of security with the silent alarm, listen-in-feature, and rapid response capability that the system provides.

Location Technologies

Length 20 minutes

Slide: Location Technologies



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Location Technologies, Continued

Location technology

Explain that any AVL system employs one or more location technologies. State-of-the-art location technology for transit is:

- Global Positioning System (GPS)

Other location technologies include:

- Signpost
- Dead-reckoning (using odometer and compass)
- Radiolocation (using other navigation systems or communications systems)

In some cases, a single technology is sufficient for position determination. Often, however, the primary location technology must be supplemented with another, due to either the environment in which the system operates or the demands of the agency's application of the AVL system.

This course focuses on GPS, but will also look at the other technologies that can combine to supplement GPS.

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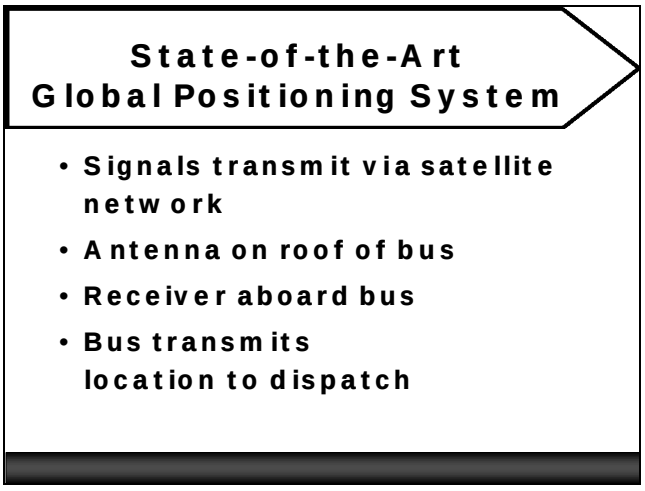
Location Technologies, Continued

Slide: State-of-the-Art Global Positioning System



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Location Technologies, Continued

State-of-the-Art Global Positioning System

Explain GPS.

GPS is a state-of-the-art radionavigation system. Twenty-four GPS satellites orbit 18,000 kilometers above the earth transmitting signals. From these signals, AVL provides the technology to calculate the location of a vehicle. The location data is transmitted to the monitoring station via a communications system.

Global positioning (GPS) works anywhere the satellite signals will reach (which is any location where a minimum of three satellites is in view to send and retrieve signals). The coverage area includes all of North America. The satellite Master Control facility is located at Falcon Air Force Base in Colorado.

A GPS/AVL system can provide up to five reports per second so the dispatcher can receive continuous feedback from the fleet. This information can be integrated with an existing computer-aided dispatch program, or used for display on an electronic map.

GPS was designed as a Defense Department method of location for the armed forces. The DoD wants to limit accuracy for civilian use, so it's currently only accurate to 100 meters. Full accuracy may be available in the future (within 20 meters or better).

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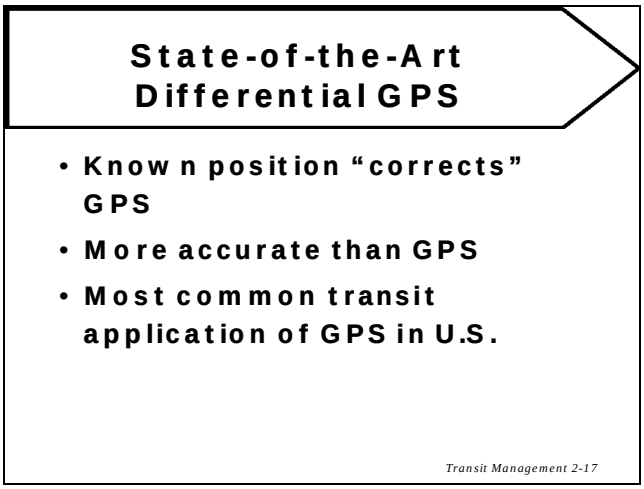
Location Technologies, Continued

Slide: State-of-the-Art Differential GPS



Differential GPS

Explain the use of differential GPS to improve the accuracy of GPS.

A differential GPS system includes a receiver placed at a stationary surveyed site (a "known position") to account for errors in position. A ground beacon can also provide the differential signal.

Applying the correction information to the GPS location information can greatly improve accuracy (to 20 meters or better) over the traditional GPS systems (which are accurate to 100 meters).

State-of-the-art transit uses of GPA

The most current common transit application of global positioning systems uses differential GPS.

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Location Technologies, Continued

Class question

Ask:

- Are any of you aware of agencies that use a GPS system?
  - ◊ Is it a differential GPS system?
  - ◊ What is it used for, or how is it used?

Ask for one or two personal stories.

Advantages and dis-advantages discussion

Ask the following questions and write the answers on the board:

- How do you think GPS systems could benefit the passenger?
- How can they benefit the agency?
- What will it do to your operating costs if you have to install and maintain this?
- What will it do to your staffing and training needs?
- What are the risks?

Review the answers.

- **Say**: Let's compare your answers with our slides.

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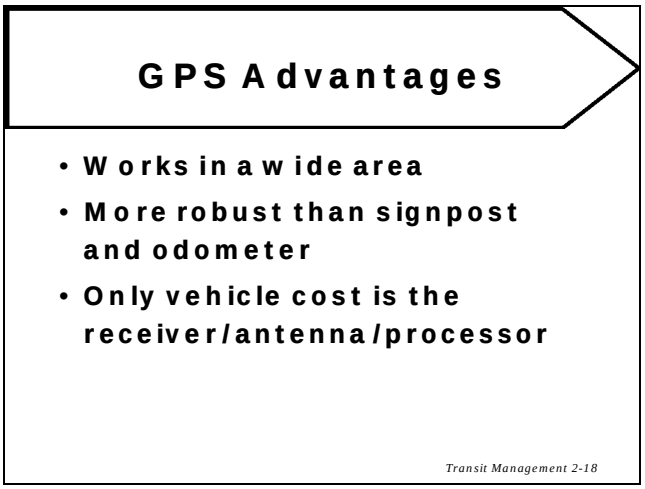
Location Technologies, Continued

Slide: GPS Advantages



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Location Technologies, Continued

GPS advantages

Review any item on the slide that was not covered already.

Compared to the other location technologies, GPS has several significant advantages, including:

- It works in a wide area.
- It is more robust and requires less maintenance than signpost and odometer.

- The satellite service is free – there is no rental fee, so your cost for the location technology is the equipment. In-vehicle costs (the costs of GPS location technology by itself) include:
  - ◊ receiver
  - ◊ antenna
  - ◊ processor: sometimes called a vehicle logic unit (VLU), which we'll talk about later in the class

Say: Of course, any location technology cannot stand by itself – the information has to be transmitted to dispatch to be of use. For now we are going to talk about just the location technology.

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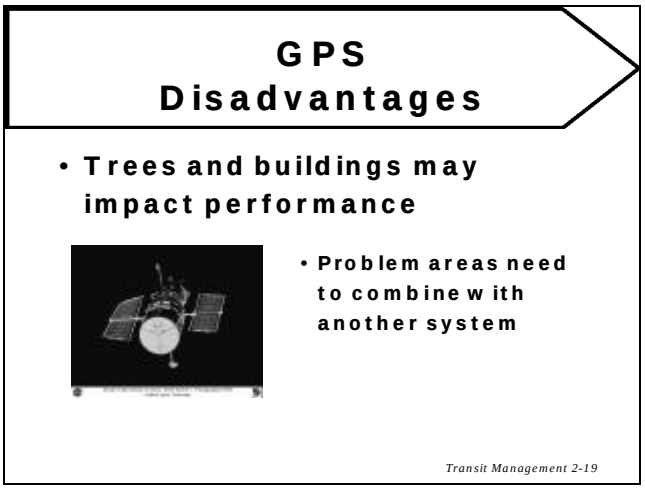
Location Technologies, Continued

Slide: GPS Dis-advantages



GPS dis-advantages

Review any item on the slide that was not covered already.

There are some disadvantages to GPS:

- It cannot reach underground (tunnels).
- It can be interrupted by tall buildings or trees.

The strengths of GPS cover the weaknesses of some of the other location technologies, and can pair nicely to work together in a combination system.

- For example, in the trouble spots of an urban canyon, where the GPS satellites may be unreliable, a few signposts can be placed to locate the vehicle until it leaves the problem area. We'll see how these combination systems work after we look at some of the alternatives to GPS location technology.

Continued on next page

Location Technologies, Continued

Estimated capital costs

A DOT nationwide APTS inventory conducted by the Volpe National Transportation Systems Center estimates the capital cost of GPS-based AVL systems at an average of $6,200 per vehicle for fleet sizes smaller than 150, and an average of $16,400 per vehicle for fleet sizes of greater than 150. The cost estimates ranged from $3,800 to $9,300 per vehicle for fleet sizes smaller than 150 (based on 7 responding agencies) and from $6,700 to $28,000 per vehicle for fleet sizes greater than 150 (based on 11 responding agencies).

Larger fleets often have what appears to be larger per vehicle costs for the whole fleet to be outfitted.

- In fact, what is actually happening is that larger scale systems are implementing more than just AVL on each vehicle – the systems are coupled with other features or technologies such as AVM, silent alarm, ATIS capabilities and tie-ins, etc.
- Remember, these costs quoted were actual costs by transit agencies that did not necessarily isolate each cost.

For more information, see the report *Operation Timesaver – ITI Transit Components* on the Internet page: http://www.fta.dot.gov/library/technology/APTS/iti/iti.htm

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Location Technologies, Continued

More cost studies

The TRB study included systems ranging from $131,779 for 135 vehicles to $38,000,000 for 2300 vehicles. Keep in mind that larger fleets often couple "add-on" features of AVL, such as computer-aided dispatch, in-vehicle sensors, silent alarm and signal priority, and these costs are included in these figures.

New York City Transit (NYCT) estimated costs at $12,188 per bus for just the location technology, where SMMBL estimated its system at $450 per bus for the location technology.

The average costs for an AVL system for the 35 agencies with almost 20,000 vehicles in the study was $12,877.91 per vehicle.

Source: *Synthesis for Transit Practice 24: AVL Systems for Bus Transit,* by Paula E. Okunieff; Transportation Research Board, 1997.

Lessons learned

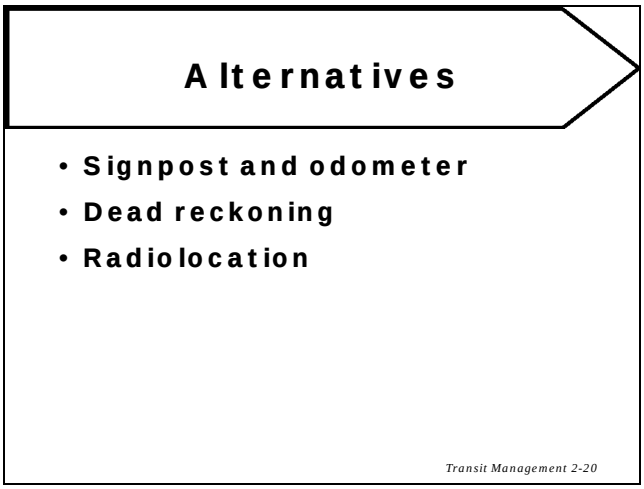
According to *Update '98* (page 2-20), the Milwaukee Transit System (MTS) in purchasing an AVL system advises:

- "careful definition of clear, reasonable objectives that meet the needs of the area and a close, positive working relationship with the vendor. Prepare a detailed specification for prospective vendors, including a phased acceptance testing program, and be realistic about the timetable for completion."

Continued on next page

Location Technologies, Continued

Slide: Alternatives



Note to instructor

Note to instructor: This material may be covered in greater or lesser depth depending on time constraints and class experience and interest.

If you do not explain the material in class, tell students that they may want to review it later.

Explain each alternative using the notes that follow, which are also in the student guides.

Continued on next page

Location Technologies, Continued

Alternative: Signpost and odometer

Signpost and odometer is a well-established technology that is becoming less popular for new applications or systems in this country. Signpost remains popular in Europe and Japan.

A series of radio beacons are mounted along a route on utility poles. These beacons have a unique ID and send out a low-powered signal that can be detected by a vehicle fitted with a receiver. When it is time for the vehicle to report, it relays the ID of the last signpost it passed to the control center, along with a measure (from the odometer) of the distance it traveled since passing the signpost. In this approach, the bus can send signals to dispatch at any point along the route.

Under an alternative strategy, it is the bus that has the unique ID, and the signposts receive the signals from the bus. This alternative method reduces both radio traffic and the need for many reserved radio frequencies, since the stationary signposts may be hard-wired into the signpost-dispatch center wireline communication link.

Signpost and odometer advantages

Compared to the other basic types of AVL location technology, signpost and odometer is one of the earliest, most proven technologies. The system has been in use with little change since 1978 when Seattle Metro used it to improve the accuracy of their bus route data. Because of this, the signpost and odometer method of location technology has been well tested.

In addition, signpost systems work in “trouble spots” like tunnels and tall buildings.

Continued on next page

Location Technologies, Continued

Signpost and odometer disad-vantages

On the negative side, signpost and odometer is the “low-tech” solution that often requires high maintenance of the signposts. Signposts can be placed only at certain locations, and the system cannot track a bus off route.

Most newer installations are not using signpost and odometer alone. Signpost and odometer combined with another technology can offer several “best of both worlds” advantages.

Alternative: Dead reckoning

In general, dead reckoning systems start with a known starting point and then calculate position based on direction and distance traveled.

- vehicle distance traveled can come from the vehicle odometer
- direction of travel can come from a compass or from wheel direction

Compass and wheel sensors

In an AVL system that uses dead reckoning, a digitally compensated solid state compass and wheel sensors are typically installed in each vehicle. These are used to measure heading (direction) and distance to "dead reckon" a new position from a previous position.

Continued on next page

Location Technologies, Continued

Inertial gyroscopes

New technology that only recently has become available includes low-cost inertial sensors (gyroscopes) for vehicles.

- In such systems, fiber optic ring gyro techniques are used to sense heading information.
  - ◊ e.g., Andrews Corp. Gyroscope Navigstar

The distance-traveled information, such as for the electronic compass, comes from wheel/odometer information.

Dead reckoning calculations

The vehicle's starting position is plotted when the sensors are first mounted in the vehicle. The system determines a new position for the vehicle by using the previous position and "drawing a line" to the new position based on the vehicle's heading and the distance it has traveled.

Dead reckoning accuracy

A good dead reckoning system can locate with only a one or two percent error rate.

- Consider that for every mile driven, the location can be off by up to 100 feet. If you drive 50 miles, the location derived by this system can be blocks away from the vehicle's actual position.
- Therefore the system must be "zeroed" out at the vehicle starting point.

Continued on next page

Location Technologies, Continued

Alternative: triangulation with radio towers

Triangulation can be used in communication systems for radiolocation. One such system operates on radio frequencies in the 900 MHz band. Transmitting and receiving towers are placed strategically throughout a region.

By triangulating on the signal transmitted from the vehicle at the receiving towers, a vehicle can be located to within 150 feet. Positions are relayed back to base stations where they are shown on display maps.

- PacTel Teletrac in Los Angeles provides service that operates on frequencies in the 900 MHz band and utilizes radio towers. Transmitting and receiving towers are placed strategically throughout the region.

Alternative: LORAN-C with radio-navigation

LOng RANge aid to navigation, the present version of which is known as Loran-C, is a land-based radionavigation system that uses low-frequency waves to provide signal coverage.

LORAN-C determines location based upon the reception of transmissions and associated timing.

LORAN-C is a “fading technology” or a “legacy system.”

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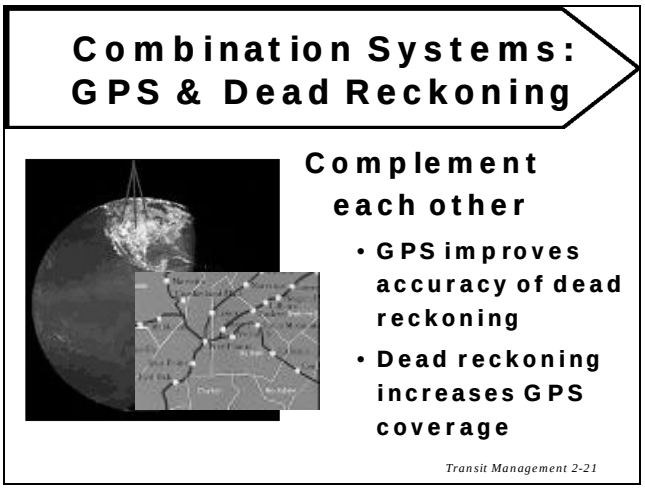
Location Technologies, Continued

Slide: Combination Systems: GPS & Dead Reckoning



Technology integration: Dead reckoning and GPS

Dead reckoning, by itself, drifts over time. GPS can correct that.

Some AVL systems combine dead reckoning, map matching and GPS: dead reckoning is combined with map matching to keep the vehicle's location matched to a map, and with GPS to correct the occasional errors.

A combination system is a more accurate solution, but is more costly than dead reckoning alone.

GPS and dead reckoning complement each other well.

Combination systems

Some companies have improved dead reckoning by adding an application of a geographic information system (GIS) called "Mapmatching." Mapmatching constantly compares the indicated vehicle position to a street location on an electronic copy of a map.

Continued on next page

Location Technologies, Continued

Technology integration: Geographic information systems (GIS)

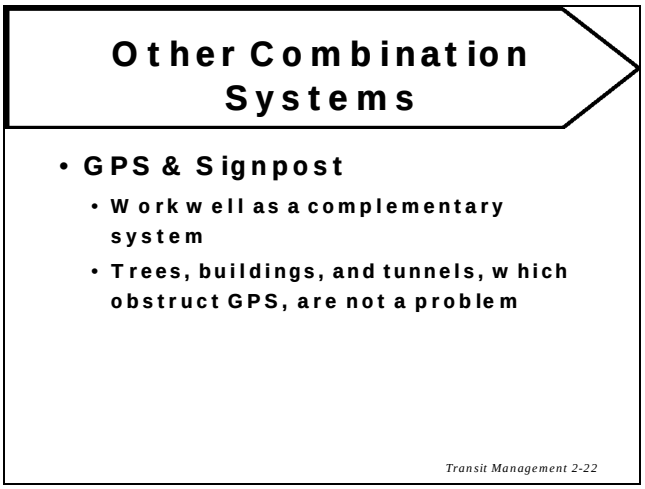
In a simple case, if the AVL system says the vehicle is heading due east, but the map shows only a road heading a bit off due east, map matching can correct the location of the vehicle to the road.

- If a correction is performed often enough, e.g., every one or two seconds, it can eliminate the small errors that will occur.
- Mapmatching also recognizes that the vehicle is not always on a road and takes this into account when making corrections.

Continued on next page

Location Technologies, Continued

Slide: Other Combination Systems



GPS and signpost

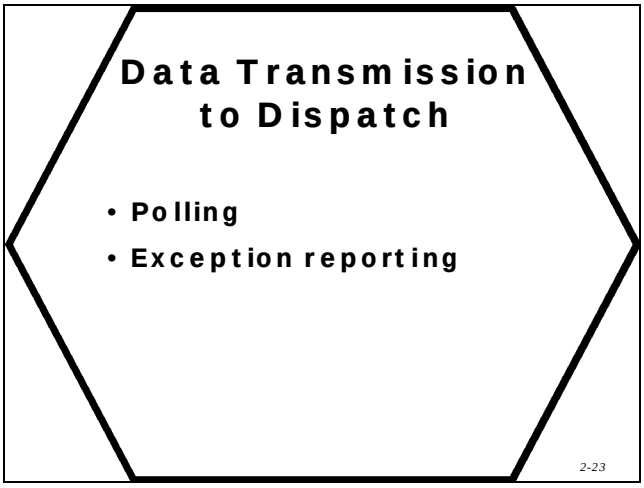
Signpost systems combine particularly well with GPS because the two complement each other.

- GPS doesn't work in tunnels and urban canyons; signposts can be placed directly in these trouble spots.

Data Transmission to Dispatch

Length 15 minutes

Slide: Data Trans-mission to Dispatch



Data trans-mission to dispatch

Explain that the second essential part of an AVL system that combines with the location technology is transmitting the data to the dispatch center.

Say: A word of warning here: this end of intelligent transportation technology – data transmission to dispatch – is high on the complexity scale. If you don't have a telecommunications expert on your staff, you will need help from an outside expert or consultant. We'll talk more about this issue as we get into the next module that focuses on transit telecommunications.

Continued on next page

Data Transmission to Dispatch, Continued

Data transmission to dispatch

Say: For transmission, an agency must decide whether to "piggy-back" the location data onto an existing voice or data radio network, or to use a stand-alone network.

- If an existing network is used,
  - ◊ Delays can be experienced in communicating locations due to the higher volumes of traffic being transmitted.
  - ◊ If the system is not designed properly, voice communications can also run into the data, causing the voice communications to be lost.

- For most fleets, a dedicated mobile radio system is often the more efficient choice.

- Microwave and cellular networks could also be used for data transmission, but they are very expensive or not secure or reliable enough for agencies to implement for AVL purposes.

- By automating data transmission to dispatch, you reduce the amount of voice information the operator must relay to dispatch.
  - ◊ decreased voice traffic in telecommunications
  - ◊ increased data burden on telecommunications systems
  - ◊ Overall, telecommunications needs will increase.
  - ◊ You must ask: can your existing system handle the increase?

Continued on next page

Data Transmission to Dispatch, Continued

Polling

Briefly **explain** the terms “polling” and “exception reporting.”

AVL systems collect short, frequent bursts of data.

The two primary methods of transmitting this data to the central dispatch are polling and exception reporting.

In polling, either the mobile data terminal (MDT) polls the central receiver or the dispatcher’s computer polls the vehicle. This could be very data intensive, depending on dispatch’s need for a given vehicle’s location.

For example, a system could poll critical response units every 15 or 20 seconds, while polling non-critical units every 60 seconds.

Exception reporting

A related alternative, exception reporting, has the vehicle automatically reporting its position to dispatch only when it is off schedule or at certain spots along the way, whichever comes first.

- This greatly reduces the data loads on the communications link.

Continued on next page

Data Transmission to Dispatch, Continued

Note to instructor

*Note to instructor: The information relating to the first slide in this lecture/discussion (called **Data Transmission to Dispatch**, slide 2-23) is essential for the student's understanding of both parts of a GPS system – the location technology and the data transmission to dispatch.*

- *The rest of this lecture/discussion is optional, depending on class interest.*
- *If you skip the optional section, resume the module at the lecture/discussion called **Examples**, slide 2-30.*

More detail (optional)

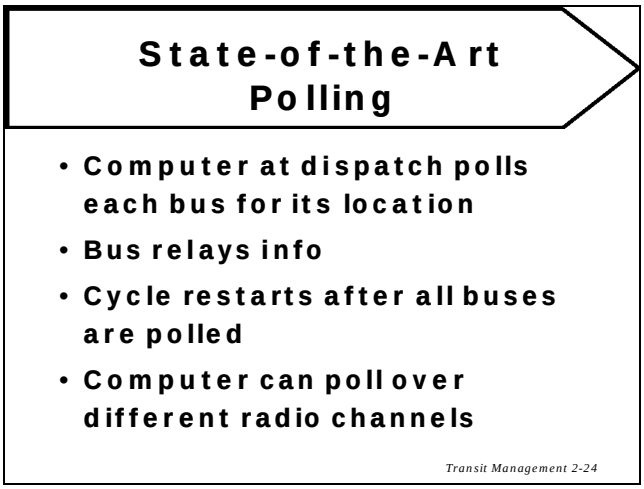
Note to instructor: look at the two alternatives in more detail if the class has interest.

Say: Let's look at these two alternatives in more detail.

Continued on next page

Data Transmission to Dispatch, Continued

Slide: State-of-the-Art Polling



Note to instructor

Note to instructor:

This is the beginning of the optional section.

Polling

Explain the details of polling.

Current solutions use a software routine that polls the vehicles for position. The polling rate is set to provide sufficient position updates for the fleet while at the same time not overloading the communication channel or the base-station computer.

- Polling tends to provide unnecessary data traffic because not all vehicles require constant position updates.

Several different methods to limit data traffic while still sampling enough known vehicle positions include:

- passive polling
- active polling
- selective polling

OPTIONAL

Continued on next page

Data Transmission to Dispatch, Continued

Class question

Ask:

- Are any of you aware of agencies that use polling in an AVL system?
  - ◊ What location technology is it combined with?
  - ◊ How many vehicles are involved?
  - ◊ What kind of cycle rates is it using?
  - ◊ How has it been working?

Ask for one or two personal stories.

Advantages and dis-advantages discussion

Ask the following questions and write the answers on the board:

- How do you think polling systems could benefit the passenger?
- How can they benefit the agency?
- What will it do to your operating costs if you have to install and maintain this?
- What will it do to your staffing and training needs?
- Can you think of any risks?

Review the answers.

- **Say**: Let's compare your answers with our slides.

Continued on next page

OPTIONAL

Data Transmission to Dispatch, Continued

Slide: Polling Advantages

Polling advantages

Review the slide item if it was not covered already.

Polling data accuracy depends on how often the buses are polled. How often the buses are polled depends on fleet size.

- The larger the fleet the longer a polling cycle takes.
- Small fleets can use this technology efficiently.
- Cycle times can also depend on the number of transmission channels available.

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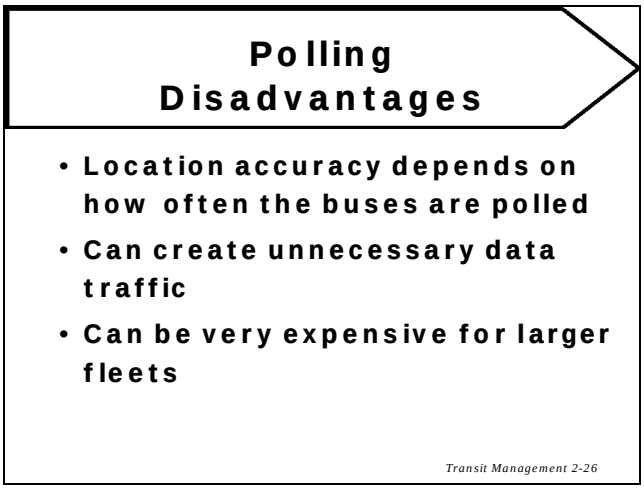
OPTIONAL

Data Transmission to Dispatch, Continued

Slide: Polling Disadvantages



Polling disadvantages

Review any item on the slide that was not covered already.

- Too much polling can create too much data traffic.
- The larger the fleet the longer a polling cycle takes
- Cycle times can also depend on the number of transmission channels available.
- If there is an increase in fleet size, the polling rate is set either at a longer time interval which holds communications constant, or the power of the communication channel and computer processor is increased to shorten the polling interval. This can be very expensive if a fleet grows.

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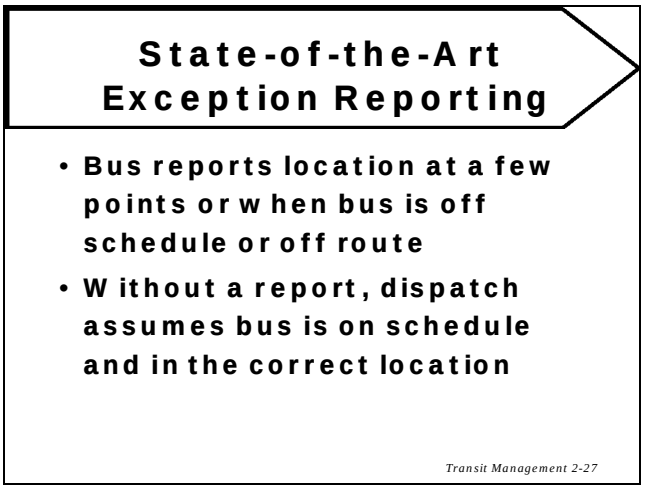
OPTIONAL

Data Transmission to Dispatch, Continued

Slide: State-of-the-Art Exception Reporting



Exception reporting

Explain exception reporting.

Many transit agencies have chosen exception reporting to compensate for the disadvantages of polling.

With exception reporting, each vehicle reports its location to dispatch only at a specific point, or when the vehicle is running off schedule beyond specified parameters.

- If there is no report, dispatch assumes that the vehicle is on schedule.

Exception reporting requires each vehicle to know:

- its position
- its scheduled position

Continued on next page

OPTIONAL

Data Transmission to Dispatch, Continued

Note

Note to instructor: This page is optional, depending on class interest.

Class question

Ask:

- Are any of you aware of agencies that use exception reporting in an AVL system?
  - ◊ What location technology is it combined with?
  - ◊ How many vehicles are involved?
  - ◊ What kind of cycle rates is it using?
  - ◊ How has it been working?

Ask for one or two personal stories.

Advantages and dis-advantages discussion

Ask the following questions and write the answers on the board:

- How do you think exception reporting systems could benefit the passenger?
- How can they benefit the agency?
- What will it do to your operating costs if you have to install and maintain this?
- What will it do to your staffing and training needs?
- Can you think of any risks?

Review the answers.

- **Say**: Let's compare your answers with our slides.

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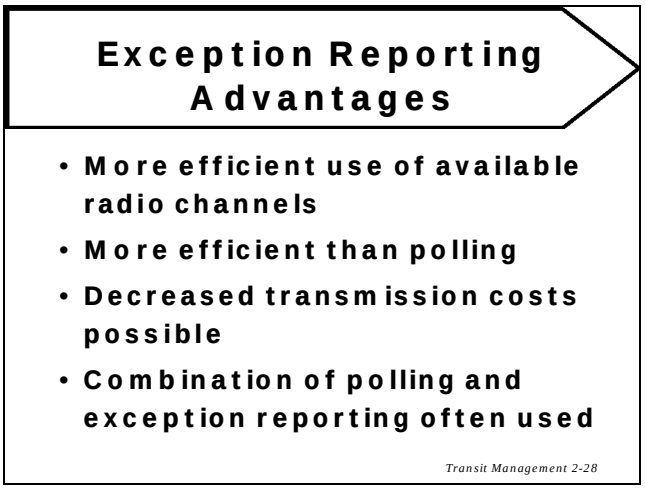
OPTIONAL

Data Transmission to Dispatch, Continued

Slide: Exception Reporting Advantages



Exception reporting advantages

Review any item on the slide that was not covered already.

- Exception reporting makes more efficient use of radio channels.
  - ◊ This can decrease transmission costs.
- This method is more efficient than polling.
- Many agencies use a combination of polling and exception reporting to take advantage of both technologies.

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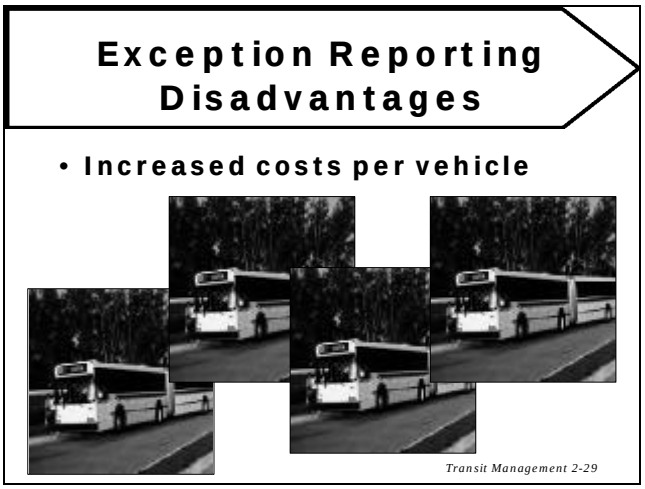
OPTIONAL

Data Transmission to Dispatch, Continued

Slide: Exception Reporting Dis-advantages



Exception reporting dis-advantages

Review the slide item if it was not covered already.

- Exception reporting requires more software than polling because it is harder to do.
- The additional complexity increases costs per vehicle.

Many agencies use a combination of polling and exception reporting to take advantage of both technologies.

Issue: How the data is used

Say: Keep in mind that location data, either from exception reporting or polling, is of little value in and of itself. The location data (where the bus is) needs to be compared to route and schedule data (where the bus should be and when).

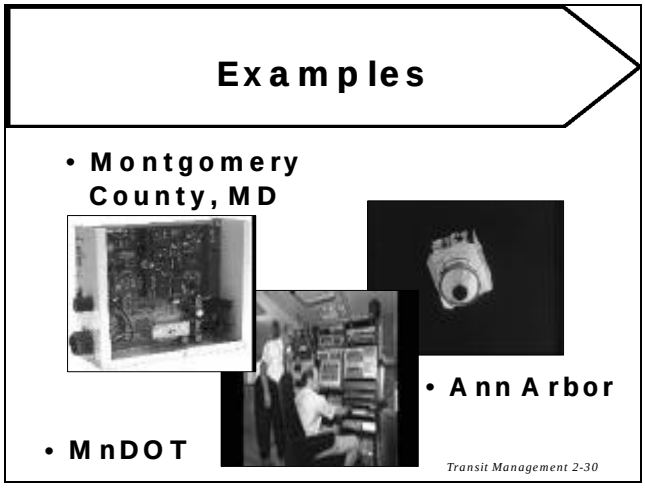
- It is also critical to relay this information to the vehicle operators because they are the ones who can adjust for any problems.

OPTIONAL

Examples

Length 10 minutes

Slide: Examples



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Examples, Continued

Transit fleet management

Remind the students that transit fleet management is one of the nine multimodal Traveler Management and Traveler Information Components of ITS. Transit fleet management shares certain location technology equipment with other components such as Emergency Management and Freeway Management.

Many technologies employed in transit fleet management are directly related to transit, including signal priority control and AVL.

- AVL can give Transit Management Centers information regarding vehicle speeds and congestion levels.

Systems exist or are being implemented in many locations, including Anaheim, Denver, Detroit, Minneapolis, Houston, San Antonio, Seattle, and Milwaukee.

- If any of the students are from any of these areas, ask them to comment briefly on their system and how traffic management is or will be integrated with transit.

Continued on next page

Examples, Continued

Mont-gomery County, MD

Say: Montgomery County, Maryland has recently developed and implemented an advanced transportation system. This system manages public transportation flow by integrating transit management with the traffic signal system, without causing gridlock for other vehicle traffic. Buses are outfitted with global positioning systems (GPS) AVL which provides real-time transit information to the transportation management control center.

The entire system includes:

- Adaptive traffic signal control
- Automated signal control
- 200-camera surveillance system
- Automated transportation information
- Vehicle tracking (GPS and others)
- Aerial surveillance operations
- Integration with future automated highway systems

Continued on next page

Examples, Continued

MnDOT

Minnesota Department of Transportation (MnDOT) Traffic Management Center has a number of projects that involve ITS for transit, under Minnesota Guidestar.

One effort, called the ARTIC (Advanced Rural Transportation Information and Coordination) project is testing the application of ITS technology in several public agencies in the rural Arrowhead region.

The project has an AVL and MDT component with functionality on 15 MnDOT vehicles, 4 Minnesota State Police vehicles and 15 transit buses. There is also an interface between the MDTs and the sand spreader control on the plow trucks.

For more information, see their extensive web site at *http://www.dot.state.mn.us/tmc/index.html*

Continued on next page

Examples, Continued

Ann Arbor, Michigan AATA

At the end of 1997, the Ann Arbor Transportation Authority (AATA) gave final approval to a new radio backbone and AVL system for their entire revenue fleet – 70 fixed-route buses and ten paratransit vehicles.

System uses:

- Differential GPS
- Dead-reckoning
- Dispatch computer stations, which control:
  - ◊ Fixed-route operations
  - ◊ Paratransit operations
- GIS maps
- CAD
- Run-cutting software
- Real-time paratransit dispatching software

Vehicles are fitted with APTS equipment such as:

- Mobile data terminals
- Automatic monitors of engine components
- AVL-integrated farebox
- Internal and external digit signs and audible annunciators
- Automatic Passenger Counters (APCs)
- Security cameras

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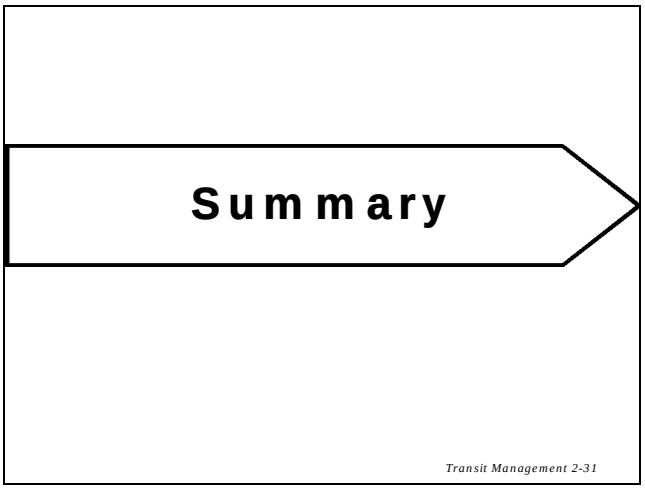
Examples, Continued

Slide: Summary



Integration discussion

Note: If there is time, this discussion can be interactive by asking questions of the students.

Say: Before we end this module, we need to discuss how integration with other agencies and modes fits in with an AVL system. Some of the items to consider include:

- the data collected from the location technology
  - ◊ type of data
  - ◊ agency policies
  - ◊ definitions of terms for agreement between agencies
  - ◊ reporting issues
- paratransit uses
  - ◊ particularly for billing and no-show policy enforcement
- the systems currently in place in your region

Continued on next page

Examples, Continued

Summary **Explain** resources that will provide students with additional information. Refer to the appendix for additional listings of related courses.

Transit Management Training Course	Title	ITS Professional Capacity Building Technical Seminars	ITS Professional Capacity Building Short Courses	NTI course
Module 2: Automatic Vehicle Location Systems	Geographic Information Systems: Transit Applications			x

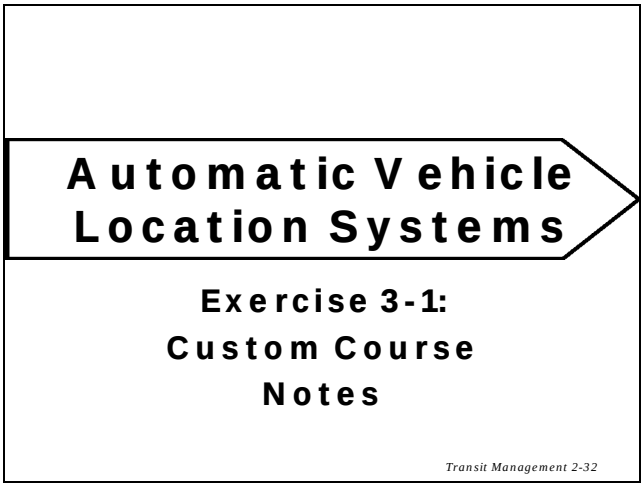
TABLE 2-1: APTS AUTOMATIC VEHICLE LOCATION SYSTEMS TECHNOLOGY REFERENCE

Technology	***Description***	***Benefits, Costs, and Risks***
State-of-the-art Location Technology		
Global Positioning System (GPS)	Technology which uses signals transmitted via a satellite network	• GPS works in a wide area at a relatively low cost • It can be interrupted by urban canyons or trees and will not work underground • Coverage is discontinuous • Accurate to 100 meters
Differential GPS	GPS system that uses a "known position" to account for errors in position	• Greatly improved accuracy over traditional GPS (to 20 meters or better)
Other Location Technology		
Signpost & Odometer	A series of radio beacons placed along the route send out a low powered signal detected by a receiver on the vehicle	• Earliest, most common technology that is well tested and reliable • Requires high maintenance and is limited by where signposts can be placed • The system cannot track vehicles off route
Radionavigation and radiolocation	Land-based radionavigation (LORAN C) and communication systems which use low frequency waves and triangulation	• Low cost and low maintenance and offers continuous coverage in all weather conditions • Triangulation offers improved accuracy • Susceptible to interference and is no longer widely used
Dead Reckoning	Vehicles determine their location from a known starting point by measuring distance traveled and by using an integrated compass	• The system has a 1 to 2 percent error rate, which is good for short distances. At large distances, the error adds up to a significant deviation. • Used in conjunction with Mapmatching and GPS to decrease error
Data Transmission to Dispatch		
Polling	A software routine at the central dispatch that polls the vehicle for its location	• Cycle times are dependent on fleet size, i.e., the larger the fleet, the longer it takes • Location accuracy is a function of polling frequency • Can create unnecessary data traffic
Exception Reporting	Vehicle reports its location at a few specific points or when off schedule	• More efficient use of radio channels • Requires more hardware and software than polling

Exercise 2-1: Custom Course Notes

Length 30 min.

Slide: Exercise 3-1



Leader instructions

Read the "In this exercise" and the directions to the class.

Say:

- Turn your student guides to the Chicago Transportation Authority case study on page _____. Read the case study, then answer the questions on page _____.

- **Allow** ten minutes for the students to read the case study and answer the questions.

Note to instructor: *This exercise continues after the questions.*

Continued on next page

Exercise 2-1: Custom Course Notes, Continued

In this exercise

You will:

- identify the challenges in your agency that can be addressed with AVL technologies
- identify the most appropriate AVL system for your agency
- identify the possible benefits of using Automatic Vehicle Location Systems in your transit systems

Directions

Read the example provided and answer the questions that follow.

Continued on next page

Exercise 2-1: Custom Course Notes, Continued

Case Study: CTA

Chicago Transportation Authority:

In April 1996, the Chicago Transportation Authority (CTA) issued a Notice to Proceed on the installation of a combination dead-reckoning/GPS system on about 1,500 of its nearly 2,100 buses. CTA expects the installation to be complete before the fall of 1999. Because of the many tall buildings lining the streets of downtown Chicago, CTA is using a combination of dead reckoning and GPS to enjoy the advantages of GPS, yet compensate for the times the GPS signals are blocked by buildings.

When the system is in place, CTA will initiate a demonstration project that will include a Bus Service Management System (see *Update '98*, Section 2.5.1), to aid dispatchers in correcting schedule deviations more quickly and easily.

The AVL will also include a Bus Emergency Communications System, a fully integrated communications base that enhances the effective delivery of bus service using a new two-way voice and data radio system (see *Update '98*, Section 2.5.1). CTA also operates APCs on 25 of its buses (see *Update '98*, Section 2.4). These are currently operated separately from the AVL, but the CTA is considering linking the two.

Source: APTS State-of-the-art Update '98, p. 2-20 to 2-21 and 2-37

Continued on next page

Exercise 2-1: Custom Course Notes, Continued

Question 1 How is the Chicago example relevant to your transit system and your region?

Question 2 What elements of the Chicago example would you need to consider for your transit agency? for your region?

Question 3 What benefits did the Chicago example demonstrate? List benefits that would apply for your transit agency.

Continued on next page

Exercise 2-1: Custom Course Notes, Continued

Turn to Module 10

When students are finished with Exercise 2-1, direct them to Module 10.

Say: Open your book to Module 10, page _____. Using the student guide's information about AVL and your knowledge of your own region and agency, customize this quick reference to help you plan when you return to your office. Respond to each item as follows:

- In **item 1**, circle the technologies that are currently used in your region. Highlight potential technology for future applications.
- In **item 2**, read each of the questions and answer yes or no. "Yes" answers suggest your interest in using AVL.
- Read **item 3** to identify which types of technology are best suited to solve particular problems.
- In **item 4**, tell the students to write their own action items and/or ideas that this module suggests to them. For example:
  - ◊ Are there any questions you want answered?
  - ◊ Were there any web sites that you wanted to look at when you return to the office?
  - ◊ Were there any courses or resources you wanted to find out more about?
  - ◊ Did we mention any transit example that you want more information about — who can you contact and where?

Continued on next page

Exercise 2-1: Custom Course Notes, Continued

For more information For additional information, use the following table to look up additional examples of what is going on in the field.

Automatic Vehicle Location Systems Examples			
Technology	**Story**	**Update '98**	**Additional info**
Combination systems	AATA in Ann Arbor, MI	p. 2-18	Differential GPS and dead reckoning
	NYCT in New York, NY	p. 2-21	Differential GPS and dead reckoning
GPS	Tri-Met in Portland, OR	p. 2-16	*Update '96,* p. 25
	RTD in Denver, CO	p. 2-17	*Update '96*, p. 24
Signpost and Odometer	King County Metro in Seattle, WA	p. 2-14	System was new in 1993. See also *Update '96,* p. 22
	New Jersey Transit in Newark, NJ	p. 2-15	New system (planning stage)